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RELATIONSHIP BETWEEN PROPULSIVE FORCE IN BREASTSTROKE AND SOME ANTHROPOMETRIC PARAMETERS OF ELITE ADOLESCENT MALE SWIMMERS

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ABSTRACT
The aim of this study was to investigate the effect of anthropometric variables on propulsive force of swimmers. Since it was not possible to purchase and implement an MAD[1] machine in Iran, an indirect method of determining active drag (IMAD) was used. The population consists of 30 adolescent male swimmers aged11-14 years old who were selected as samples - due to low quantity, the population could not be larger. Over the last year, swimmers have been training three times a week on average and they are members of Qazvin selected team. The longitudinal, latitudinal, environmental and body composition anthropometric variables were measured which included: standing and sitting height, length of two open hands, arm length, forearm length, length of palms, thigh length, shin length, foot's length, shoulder and hip width, diameter of wrist, ankle, elbow, knee, arm size in rest, arm size in contraction mood, thigh size at rest, thigh size in contraction mood, size of chest, waist, hip, head, weight, lean mass and weight of fat mass. The results indicated that except sitting height, length of arm, forearm, palms, hip, ankle and knee width and fat mass weight, remaining anthropometric variables had a meaningful relation with propulsion. According to the results of the research, the best Breaststroke Swimmers are the ones who are mesomorph, and relatively have high weight and lean mass, their shoulder and hip are wider than other swimmers. In addition, they are tall, and their hand, shin and foot are long. These parameters are important in propulsive force in breaststroke swimming.

KEY WORDS: Anthropometry, Average speed, Breaststroke, Max speed, propulsive force, Swimmers

INTRODUCTION

When the swimmers put the water backward by their body, according to Newton's third law, equal and opposite force is generated and the swimmer pushes the water forward. Of course, this reaction force in the fluid medium rarely is in the same direction of the movement and it is composed of lifting and resistance forces, outcome of both forces helps progress of the swimmer (Astagr and Tanner,2007). Determining the force is a fundamental issue in biomechanical studies and most studies would be vain without calculating it. Thus, necessity for using ways which can measure this variable without need for complex tools is felt. Understanding relationship between anthropometric parameters and the force is very crucial, so that appropriate selection of the athletes in each sport fields considering their body physical structure and physical capacities prevent from wasting time and inappropriate investment (Bahadoran, 2007). Swimming acts differently at each moment in using different organs and specific muscular groups. In this sport field which is subject to mechanical rules, anthropometric parameters are certainly effective in quality of performingfour swimming skills (Bahadoran, 2007). Breaststroke swimming is the slowest competitive swimming and it undergoes technical changes in an accelerating rate compared to any other competitive swimming, thus investigating propulsive force in which is very crucial (Castile *et al.,* 1996).

Swimmers in the swimming fieldsin 50-500 m distance and even 25 km and thus physical size and shape varies by different branches of this field. Inherentability of each swimmer in compatibility and response to the exercise program has considerable effect on the results. Therefore, coaches should seek for athletes with the highest talent in achieving the success, however, most physical properties of the swimmer are observed within his genetic capacities which cannot be changed by the coach in the exerciseprogram (Memari, 2002). Attention of the authors in physical education has been always toward champion making for participatingin international competition (Kashif, 1989). Meanwhile, physical properties of athletes are one of the things that contribute to the championing, and many research works have been conducted in this field: Barghamadi *et al.,* (2012), Rosemann (2010), and Shahheydari *et al.,* (2011), Latt *et al.,* ,

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(2010), Hlavaty (2010), Sekulic *et al,* (2007), and Jagomagi and Jurimae (2005) reported relationship between progress of the swimmers and length of the limbs, and predicted the main anthropometric factors associated with breaststroke 100 m swimming are height and length of foot. Carter and Ackland (1994) found breaststroke swimmers have the shortest physical body and backstroke and free swimmers have the tallest physical body. They also reported higher thigh width in the breaststroke swimming. Bahadoran (2007) reported significant relationship between arm diameter and propulsive force. Gaeeni *et al.*, , (2007) found there is significant relationship between chest depth and 50, 100, 400, and 800m free swimming records and 50 and 100m breaststroke swimming. Gaeeni *et al.*, , (2005) reported relationship between hip width and fast performance. Sabaghianrad (2004) found relationship between propulsive force and wrist diameter. Barghamadi and *et al.,* (2012) found there is significant relationship between speed of swimmers and their arm diameter. Ostrowska *et al.,* (2006) reported importance of the circumference of muscles, trunk, upper and lower limbs in the young swimmers. Carter and Ackland (1994) showedlarger hip circumference at the breaststroke swimming. Gaeeni *et al.,* (2007) found there is significant relationship between hip circumference of subjects with 800m free swimming records and 50m breastroke swimming record, and Sabaghniarad (2004) observed significant relationship between propulsive force andchest circumference and arm circumference. Barghamadi *et al.,* (2012) reportedrelationship between the weight and speed of the swimmers. Martinez *et al.,* (2011) compared anthropometric indices of male and female adult swimmers and found subcutaneous fat in the triceps, the pelvis and abdomen is higher in female swimmers than male swimmer. Latt and *et al.,* (2010) reported relationship between bone mass and speed of swimmers. Rosemann (2010) found significant relationship between weight and competition time period. Hlavaty (2010) predicted relationship between the weight and swimming performance. Sekulic *et al.*, , (2007) found there is relationship between the weight and 50 and 400m free swimming. . Carter and Ackland (1994) found male and female swimmers in 25km swimming have higher fat compared to other groups. Bahadoran (2007) reported relationship between the weight and fat free weight of the swimmers and propulsive force. Gaeeni *et al.,* (2005) observed relationship between *subscapular subcutaneous-fat thickness index and speed and endurance performance. These findings help the authors to consider* longitudinal, latitudinal, and environmental and body composition anthropometric variables *as effective variables. Thus, the current work aims at investigating relationship between propulsive forces in breaststroke swimming with some* anthropometric variables *in* elite adolescent male swimmers**.**

MATERIALS AND METHODS

Methodology

Current work is of descriptive – correlation type and it was conducted in field way. Statistical sample included 30 male adolescent swimmers (aged 11-14) in Qazvin Province. These swimmers had been prepared for participating in the national championship competitions in the swimming school since their childhood and had ability for breaststroke swimming with its techniques. They have had continuous exercise three times a week over last year and were members of Qazvin selected team.

In order to measure anthropometric indices, digital caliper, chronometer, wall-mounted stadiometer and tape meter were used.Inbody230 device was also used to measure the body composition. Anthropometric properties of the swimmers were measured and in order to indirect measurement of the resistant force, firstly a line was specified as the start line in the pool and another line in 10m distance to the start line was spotted as the end point. Then, tape meter was installed in 10m length from 10m end point so that slipping distance is measured accurately. The swimmer approached to the start point slowly and he started breaststroke swimming by his maximum speed upon arrival of his head behind the start line. Chronometer started working simultaneously during the 10-meter distance. Once the swimmer head crossed the finish line, the whistle was sounded, chronometer stopped working and the swimmer stopped his activity, and he slide the remaining distance on the water, so that he reached to stationary state on water. In this state, sliding distance and 10m swimming time was recorded from chronometer. Each swimmer performed this test three times with at least 30min time intervals, and mean of tests were registered as his record.
With 10m swimming time, the speed can be calculated according to relation (1):

$$\overline{V} = \frac{\overline{\mathrm{X}}}{t}$$

Since passed distance is 10m, Relation (1) is rewritten as Relation (2):

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$$\overline{V} = \frac{10}{t}$$

Where, t: 10m swimming time

$\overline{V}$: is average speed of a swimmer in the 10m swimming.

Shahbazi Moghadam and Sanders (2002) considered water resistance force proportionate to $C_1V + C_2V^2$ for propulsive force measurement, thus:

$$C_1 = 2mv/(x+10)$$

$$C_2 = M/X$$

$$V_L = \frac{1}{2}\left[C_1/C_2 + \sqrt{(C_1/C_2)^2 + (4MV/C_2t)}\right]$$

$$F_p = C_1V_L + C_2V_L^2$$

M: swimmer mass, X: sliding distance, C_1: Resistance coefficient 1, C_2: Resistance coefficient2, Vt: average speed, FP: propulsive force Considering above formulae, force measurements were conducted. Obtained speeds and distances were recorded and placed in the relations, and resistance coefficients and propulsive force were measured for each swimmer. Anthropometric data for the swimmers were also collected. Body composition data for the swimmers obtained from Inbody system were collected and data were stored in an Excel File and tables were drawn. Descriptive statistics were used for calculating mean and SD and Pearson correlation coefficient was used for determining correlation of the variables.

RESULTS

Research findings include descriptive statistics related to anthropometric properties and results for Pearson correlation coefficients and propulsive force illustrated in Tables 1-5.

Table 1. gives descriptive statistics related to anthropometric properties for subjects ‘upper extremities and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke.

Table 1. Descriptive statistics related to anthropometric properties for subjects ‘upper extremities and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke

	significant	r^2	R	D	Mean	N	Anthropometric properties
No correlation	0/318	0/035	0/189	2/99	29/40	30	Aim length (cm)
No correlation	0/058	0/122	0/350	2/97	24/23	30	Forearm length (cm)
No correlation	0/081	0/104	0/323	1/58	17/51	30	Length of palm (cm)
Correlated	0/005*	0/253	0/503	0/91	7/19	30	Elbow diameter (cm)
Correlated	0/005*	0/251	0/502	0/44	5/20	30	wrist diameter (cm)
Correlated	0/005*	0/248	0/498	3/02	25/10	30	Arm at rest (cm)
Correlated	0/001*	0/311	0/558	3/15	26/83	30	Contracting arm circumference (cm)
*** denoting significant relationship (P < 0.05)**							

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Table 2 shows descriptive statistics related to anthropometric properties for subjects' lower extremities and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke.

Table 2.Descriptive statistics related to anthropometric properties for subjects' lower extremities and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke

	significant	r^2	R	D	Mean	N	Anthropometric properties
No correlation	0/120	0/084	0/290	4/08	42/07	30	Thigh Length (cm)
Correlated	0/028*	0/160	0/401	4/08	39/37	30	Shin length (cm)
Correlated	0/008*	0/228	0/478	2/28	24/70	30	Foot Length (cm)
No correlation	0/052	0/128	0/358	0/77	10/76	30	Knee diameter (cm)
No correlation	0/310	0/036	0/192	0/98	7/02	30	Ankle diameter (cm)
Correlated	0/001*	0/310	0/557	4/84	47/55	30	Thigh circumference at rest (cm)
Correlated	0/002*	0/289	0/538	4/76	48/18	30	Thigh circumference in contraction (cm)
Correlated	0/000*	0/384	0/620	3/55	33/47	30	Shin circumference at rest (cm)
Correlated	0/000*	0/365	0/604	3/53	34/15	30	Shincircumference at contraction (cm)
*** denoting significant relationship (P < 0.05)**							

Table 3. shows descriptive statistics related to anthropometric properties for subjects' trunk and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke.

Table 3. Descriptive statistics related to anthropometric properties for subjects' trunk and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke.

	significant	r^2	R	D	Mean	N	Anthropometric properties
Correlated	0/010*	0/212	0/461	2/83	38/20	30	Shoulder width (cm)
Correlated	0/004*	0/260	0/510	2/27	28/53	30	Hip width (cm)
Correlated	0/000*	0/447	0/669	8/00	82/81	30	Chest circumference (cm)
Correlated	0/003*	0/280	0/529	7/83	75/90	30	Waist circumference (cm)
Correlated	0/005*	0/245	0/495	7/65	78/90	30	Hip circumference (cm)
*** denoting significant relationship (P < 0.05)**							

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Table 4 gives descriptive statistics related to standing and sitting height, length of two open hands, and head circumference anthropometric properties of the subjects and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke.

Table 4.Descriptive statistics related to standing and sitting height, length of two open hands, and head circumference anthropometric properties of the subjects and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke

	significant	r^2	R	D	Mean	N	Anthropometric properties
Correlated	0/010*	0/212	0/461	2/83	38/20	30	Standing height (cm)
Correlated	0/004*	0/260	0/510	2/27	28/53	30	Sitting height (cm)
Correlated	0/000*	0/447	0/669	8/00	82/81	30	length of two open hands(cm)
Correlated	0/028*	0/160	0/400	1/60	55/08	30	Head circumference (cm)
*** denoting significant relationship (P < 0.05)**							

Table 5 shows descriptive statistics related to anthropometric properties for subjects'body composition and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke.

Table 5. Descriptive statistics related to anthropometric properties for subjects'body composition and results for Pearson correlation coefficient for relationship between anthropometric properties and propulsive force in breaststroke

	significant	r^2	R	D	Mean	N	Anthropometric properties
Correlated	0/000*	0/387	0/622	12/05	53/57	30	Weight (kg)
No correlation	0/101	0/093	0/305	5/96	12/58	30	Fat mass weight (kg)
Correlated	0/001*	0/346	0/588	9/64	40/98	30	Lean body weight (kg)
*** denoting significant relationship (P < 0.05)**							

DISCUSSION

Obtained results indicate standing height is correlated significantly with propulsive force in *breaststroke*(r = 21%). Barghamadi *et al.,* (2012), Latt *et al.,* (2010), Jagomagi and Jurimae (2005), Shahheydari (2011), Bahadoran (2007) also found this result. Knechtle *et al.,* (2008) in their work entitled *Correlation of anthropometry and race performance in ultra-endurance swimmers* and Knechtle *et al.,* (2010) in their work entitled *What influences Race performance in Male open. Water, ultra-Endurance swimmers* found no relationship between the height and progress of the swimmers. Among longitudinal sizes of the swimmers, feet length is correlated (r = 22.8%) with propulsive force in breaststroke. It seems feet length is important for producing propulsive force when taking the water by the feet (creating attack angle). Bahadoran (2007) found significant correlation (r = 57%) between feet length and propulsive force. Considering significant level α = 5% and correlation coefficient r = 19.5%, length of two hands is significantly related with propulsive force in breaststroke. It seems that hands paly important role in producing propulsive force when taking the water and in inward rotation phase. According to fluid mechanics, the longer hands generate more extension at surface unit and thus the resistance of the water against the hand increases. Therefore, long hands help increased extension length per second and thus extension effect is increased. Ostrowska and *et al.,* (2006), Bahadoran (2007), Gaeenin *et al.,* (2007), and Sabaghianrad (2004) observed similar findings. According to the works by Knechtle *et al.,* (2008, 2010), who investigated anthropometric properties in high-endurance of the swimmers, stated there is no correlation between anthropometric properties and record of high-endurance swimmers in open waters. Shinlength is also an important feature in breaststroke swimming. Findings indicate there is significant correlation (sig level α = 5%, r = 16%) between shin length and propulsive force. Considering biomechanics, feet movement is important in creating effective attack angle in breaststroke swimming (in knee flexion and outward rotation of the feet).

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Jagomagi and Jurimae (2005) studied flexibility and anthropometric properties in *breast stroke*s wimming and declared feet length as the most important anthropometric factor. Bahadoran (2007) investigated relationship between propulsive force in backstroke swimming and anthropometric properties and found there is significant relation between length of lower extremities and propulsive force. Shahheydari (2011), Mokaram (2007), and Memari (2002) stated there is no significant relation between lower extremities length and record of the swimmers. Lack of relation may be attributed to the type of swimming and test method, since current work and Bahadoran's work tested propulsive force and Jagomagi and Jurimae used 100m breaststroke test, while other test were used in the works which reported lack of relation. For example, Shahheydari used 50m free swimming, Mokaram used 4 × 50m individual medley, and Memari used 50 and 200m backstroke tests, and all used record of the swimmers as their criterion. Among latitudinal sizes, hip width with a correlation coefficient of r = 26%, diameter of the elbow with a correlation coefficient of r = 25.3%, diameter of the wrist with a correlation coefficient of r = 25.1 and shoulder width with a correlation coefficient of r = 21.2 at significance level of $\alpha = 5\%$ are significantly correlated with propulsive force in breaststroke swimming.

The higher is diameter of the wrist and elbow diameter, the force imposed on the water in extension phase from the hand to the water is higher. Thus, according to the Newton's third law, reaction force is imposed in the opposite direction (for progress) in proportionate with the force imposed by the hands. Also, regarding shoulder width and hip width, it can be said the more is cross section; water resistance against cross section is increased. Considering analytical formula of propulsive force ($Fp=C_1V\iota+C_2V\iota^2$), propulsive force is directly proportional to the resistance coefficient, thus, the higher is resistance coefficient, there is more propulsive force. Gaeeni *et al.,* (2005) in relation with anthropometric properties of elite male swimmers in the sprint and endurance performance found there is significant relationship between hip width and sprint and endurance performance. They also found no relationship between shoulder with and performance of the swimmers. Shahbazi Moghadam *et al.,* (2000) studied relationship between anthropometric properties and speed and force in the elite swimmers in backstroke swimming and found significant relationship between elbow diameter and speed and force, and didn't find any relationship between shoulder width and wrist diameter with the speed and force.

It is probable due to rotation around body vertical axis in swimming, no relationship regarding shoulder width was found in backstroke swimming, because rotation goes to about half blade level. Regarding lack of relationship for wrist diameter, it can be attributed to the different pattern of hand under water in backstroke, since effective attack angle occurs by elbow flexion, which is consistent with this work finding. Also, Bahadoran (2007) and Sabaghian (2004) stated there is significant relationship between propulsive force and wrist diameter. Shahheydari (2011) and Mokaram (2007) reported no relationship between shoulder width and hip width and the performance. Also, Gaeeni *et al.,* (2007) and Sabaghianrad (2004) reported lack of relationship between shoulder width and progress of the swimmers. Inconsistent findings can be attributed to the different movement pattern type in the breaststroke compared to other types of the swimming. According to the results of the research, there is significant relationship between all anthropometric properties and propulsive force in breaststroke swimming. As mentioned earlier, larger cross section as analytical equation of propulsive force ($Fp=C_1V\iota+C_2V\iota^2$) leads to more progress of the swimmers. In addition, regarding circumference of the muscles it can be said that the bigger muscles will produce more torque. Barghamadi *et al.,* (2012) investigated biomechanical factors in 200m free swimming and their relationship with anthropometric properties and found there is significant relationship between swimmer speed and arm circumference. Latt *et al.,* (2010) considered arm size as the most important anthropometric criterion in 100m backstroke. Bahadoran (2007) found there is significant relationship between arm circumference in contraction and rest states and propulsive force in backstroke. Also, Ostrowska and *et al.,* (2006) analyzed anthropometric properties in 80 swimmers in Verokal Sport School and found circumference of the muscles and circumference of lower and upper extremities as well as chest circumference are important for young athletes. Sabaghianrad (2004) investigated relationship between propulsive force in butterfly stroke and anthropometric properties and observed chest circumference and arm circumference are significantly related with propulsive force in the swimmers.

Tabatabaeeian (1996) reported relationship between shin circumference and professional swimming time. Shahbazi Moghadam (2000) found there is significant relationship speed and force with arm circumference, chest circumference and head circumference in backstroke swimmers. Carter and Ackland (1994) reported larger hip width and circumference in the *breast stroke*and it was attributed to more use of the feet. Shahheydari (2011) found chest circumference, waist circumference, hip circumference, thigh circumference; shin and arm are significantly related with

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performance in the elite female swimmers in 50m free swimming. It can be attributed to the difference in the sex and age of the subjects, since subjects in the current work were adolescent male swimmers with age average 12.40 ± 1.01, while swimmers in the Shahheydari's work were young female swimmers with age average 15.92 ± 1.12. Considering the fact that puberty occurs in the younger ages in the girls, it can be the reason for difference in the findings of this work. Also, results indicated there is significant relationship between weight variables ($\alpha = 5\%$, $r = 38.7\%$) and lean body weight ($r = 34.6\%$) with propulsive force. Considering these findings, it can be said the higher is the weight and lean body weight in the breaststroke swimmers; they will be able to produce more propulsive force. Barghamadi *et al.*, (2012), Rosemann (2010), Hlavaty (2010), Sekulic *et al.*, (2007), Ostrowska and *et al.*, (2006), Bahadoran (2007), Sabaghianrad (2004), Shahbazi Moghadam *et al.*, (2000) and Tabatabaeeian (1996) reported relationship between the weight and performance and progress of the swiimers. Knechtle *et al.*, (2008, 2010), Shahheydari (2011), Mokaram (2007), Gaeeni *et al.*, (2007), and Gaeeni *et al.*, (2005) stated weight is not an important factor in performance and progress of the swimmers. Also, Bahadoran (2007) and Tabatabaeeian(1996) stated relationship between lean body weight and progress of the swimmers.

Gravity of an object is considered as a relation for measurement of buoyancy of an object and it is ratio of the object to its same volume water weight, which is determined by physical combination and composition of the object or human body. Considering different tissues of the human body (fat, muscle, and bone) there is different buoyancies (fat gravity: 0.8, muscle gravity: 1, and bone gravity is about 1-15). If gravity is higher than 1, the object would be soaked deeper in the water and buoyancy is reduced. Thus, current work is inconsistent with the theoretical principles and its reason may be the type of breaststroke swimming and location of the lower extremities of the swimmer under water for imposing force and displacement more water volume.

CONCLUSION

Considering findings of the current work regarding elite breaststroke swimmers, it can be stated the best Breaststroke Swimmers are the ones who are mesomorph (lean muscularly), and relatively have high weight and lean mass, their shoulder and hip are wider than other swimmers. In addition, they are tall, and their hand, shin and foot are long. These parameters are important in propulsive force in breaststroke swimming. This fact should be considered by the coaches and talent finding centers.

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